1985

Effects of Partial Homogenization of Milk on Yield and Quality of Cheddar Cheese

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EFFECTS OF PARTIAL HOMOGENIZATION OF MILK ON YIELD AND QUALITY OF CHEDDAR CHEESE

BY

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A Thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science
Major in Dairy Science
South Dakota State University
1985

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

My sincere gratitude to Dr. Kenneth R. Spurgeon for his patience and guidance during the period of this study. Special thanks are extended to Dr. John Parsons, Dr. George Torrey, Dr. Robert Baer, and Professor Shirley Seas for their support. Many thanks to Dr. Lee Tucker for his assistance in statistical analyses of the data.

Sincere appreciation and many thanks to the Valley Queen Cheese Factory, Milbank, South Dakota, for financial support of this project. Thanks are extended to the SDSU dairy plant personnel for their cooperation and help during the manufacture of cheese used in this study.

My fellow graduate students are appreciated for their help in times of need and friendliness. I am indebted gratefully to my parents for all their love and support. This thesis is dedicated to my loved ones.

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INTRODUCTION

In the past decade, the cheese industry in the United States (US) has grown rapidly, with cheese sales increasing by 33% (36). The cheese industry, in 1983, utilized 29.2% of total US milkfat supply as compared to 20.3% utilization in 1973 (36). Compared to the total cheese production of 2,059,228 kg (4,539,822 lb) in 1982, 2,185,611 kg (4,818,449 lb) of cheese were manufactured in 1983 in the US (36). The increased production of cheese was made possible by modifications in the cheese making process and advent of modern equipment; and it was fostered by increased demand and higher prices.

One of the recent concepts in the cheese industry is use of preconcentrated milk for cheese making. Preconcentration of cheesemilk lessens the problems related to whey disposal. With reduced bulk and increased solids level in the raw material, increase in cheese production can be attained without increase in labor or equipment. Research also has indicated increased cheese yields can be obtained by preconcentrating cheesemilk (6). Since ultrafiltration is not legal for treating milk to be used in Cheddar cheese manufacture, vacuum concentration is employed.

Vacuum concentration of milk involves considerable amount of agitation by pumping. This physical abuse of milk has a shattering effect on milk fat globules, which is similar in nature to homogenization, but not to as great an extent.

Since the natural distribution of milk fat globules and milk proteins is modified by homogenization, it is presumed that this process modifies the properties of cheese curd. Even though some researchers (15,30,38) found increased cheese yields with homogenized milk, the reports (18,39) of its adverse effects on flavor and body of cheese cast doubt on the feasibility of homogenization of milk in Cheddar cheese making. As earlier research with homogenized milk was not totally applicable to cheese making with the modern equipment used in the dairy industry, it seemed practical to investigate the effects of homogenization of milk at various pressures on the properties of the resultant Cheddar cheese during making and curing.

LITERATURE REVIEW

Cheese is a concentrated milk product with a matrix of casein holding moisture and fat (15,27). Nutritionally, cheese is a concentrated form of energy and an excellent source of proteins, calcium, and phosphorus (11,28). Most cheeses are made from the curd obtained by coagulation of casein with the help of rennet or similar enzymes in the presence of lactic acid. Cows' milk is predominantly used in cheese making; milk from other mammals such as sheep, goat, and buffalo may be used to make different cheese varieties (28).

Cheddar Cheese

Cheddar is probably the best known cheese around the world. Many variants of this cheese such as American, Australian, Canadian, and New Zealand Cheddar are now recognized (11,28). The town of Cheddar located in the county of Somerset in southwestern England is the place of origin of this cheese (28). American Cheddar cheese has cohesive body, waxy texture, and generally bland flavor. The color of Cheddar cheese is variable, yellow or white, without mottles (28).

Under the Federal Standards of Identity (16) , Cheddar cheese has been defined as containing not more than 39.0% moisture, and having not less than 50.0% of the dry matter as fat. Cheese may be made from either raw or heat-treated milk. If made from raw milk, the product must be aged for at least 60 days at a temperature not greater than 1.67°C (35°F) (16). Typical American Cheddar cheese contains 63% total solids, which include 25% protein and 32% fat (28). The mineral ash content of Cheddar cheese is about 4.1%; the added salt 1.5% by weight of the cheese (28). Cheddar cheese generally has a pH of 4.8 to 5.3 (57). Development of acidity, aided by the added starter organisms, plays an important part in the quality of ripened Cheddar cheese (31). Heat treatment and standardization of cheesemilk to have a casein-to-fat ratio of .70 help in maintaining a good and uniform quality product (11). Standardization of cheesemilk also aids in attaining the legal standards for the product and improving the yield of cheese (28); but is not always economically advantageous (41).

Factors Affecting Yield of Cheese

Normal yield of Cheddar cheese for milk pricing in the United States is accepted as 10.1 kg/100 kg milk (6). The actual yield of cheese, however, may vary depending on many factors.

Milk composition

Since cheese is a concentrated form of milk solids, the quantity of cheese obtained per unit of milk is affected by the composition of milk. The chemical composition of milk, especially the fat and protein contents, is affected greatly by factors such as species, breed, stage of lactation, feed, season, etc. (29,58). A study done by Spurgeon et al. (48) showed seasonal variations in cheese yields had a direct relationship with the variation patterns for casein and fat in milk. Proper ratio of casein-to-fat in milk is important for realizing optimum cheese yields (11,53). An increase in fat content results in a lower proportion of protein in relation to the fat content of milk. With less casein present, the water-binding capacity of cheese decreases, yielding lower quantities of cheese per kilogram of fat in milk (11,29).

Heat treatment of milk for cheese manufacture

Cheesemilk is generally heat-treated/pasteurized to destroy spoilage organisms and to have uniformity of quality of finished product. Results of studies have indicated that heat treatment of cheesemilk increases yield of cheese. Melachouris and Tuckey (35) reported increases in moisture and salt content of Cheddar cheese made from milk heated at different temperature increments. Dzurec and Zall (13) showed increases in cottage cheese yields with the use of milk heat-treated at sub-pasteurization temperatures. It is evident that heat treatment of milk induces an association between casein and whey proteins (47). It is believed that because of partial denaturation of whey proteins during heat treatment, disulfide bonds are formed among whey proteins and between whey proteins and casein. Mechanisms such as calcium linkages between whey proteins and casein may also take part in augmenting cheese yields. Dzurec and Zall (14) have suggested part of the increase in cheese yield could be due to retention of β-casein in the casein micelle, which without heat treatment would have dissociated and become solubilized in milk serum during cold storage of milk (1,9). Cheese made from heat-treated milk does not show a tendency to retain more fat (35). Although cheese yields can be increased with high heat treatment of milk, the final product tends to have inferior flavor, body, and texture (55). This negative effect on the quality of final product induces most manufacturers to use near-pasteurization temperatures for heat treatment of cheese milk.

Losses of casein in whey

Since casein is the major protein in cheese, loss of casein in whey affects the yield of cheese. Casein loss in whey occurs in the form of soluble enzymatic breakdown products of casein, and more critically, filterable curd fines that are expelled into whey at draw. Van Slyke (53) estimated about .1% of milk casein is lost in whey. His proposed formula for estimation of Cheddar cheese yield involves the supposition that about 96% of milk casein is recovered in cheese solids. Results of recent studies (6,7) showed casein recoveries averaged near 96% but had considerable variation. Barbano and Sherbon (7) indicated the true casein recovery in cheese might be lower than the assumed value of 96%, since about 1% of total protein in normal Cheddar cheese is whey protein. They reported the average true casein recovery to be 93.9%. Casein loss in whey is also aggravated by factors such as inferior quality of milk, improper curd formation, and unskillful handling of curd.

Losses of fat in whey

Excellent recovery of fat in Cheddar cheese is of significant importance, as at least 50% of the cheese total solids have to be milk fat. Kilograms of cheese obtained per kilogram of milk is affected by the efficiency of fat recovery. The Van Slyke equation is based on the assumption that 93% of original milk fat is recovered in the finished Cheddar cheese. However, under practical conditions, the fat recovery was reported (6,7) lower than 93% of original milk fat. Barbano and Bynum (6) reported fat losses of 5.8 to 8.1% in whey. McDowall, as cited by Wilster (57), reported an average fat loss of 6.0 to 6.4%. The ratio of casein-to-fat in original milk plays a critical part in loss of fat in whey. Generally, as the ratio of milk casein-to-fat decreases, the fat content of whey at draw increases (7,53). Fat losses in whey can be reduced by certain precautions such as standardization of cheesemilk to contain proper casein-to-fat ratio, and proper handling of coagulum. Modification of the physical nature of milk fat globule has been shown to be effective in reducing the fat losses in whey (6,18,38).

Miscellaneous

Apart from the above discussed factors, many others contribute to realization of the expected cheese yield. Moisture content influences not only the quality of cheese (28) but also its yield (57). Moisture in cheese does not depend upon the water content of the milk. Milk with larger proportions of casein tend to retain larger amounts of water in the cheese. Van Slyke (53) showed increases in the yields of cheese directly related to the increases in moisture content of cheese.

Along with the control of cheese moisture, salt content of cheese influences the yield (57). Average salt content of Cheddar cheese ranges from 1.5 to 1.8% by weight of cheese. Other factors which can be controlled include human errors such as handling losses of milk and cheese curd, inaccurate weighing of milk and cheese, erroneous testing of milk, etc.

Milk Fat and Globule Membrane

Milk fat is the most variable constituent of milk and is present in milk in the form of myriads of small globules. The globules vary from one-tenth to twenty microns in diameter and average about three microns in diameter. There are more smaller globules (<1 micron diameter) in cows' milk but the bulk of fat in milk is represented by the larger globules (8). The distribution of milk fat globules is dependent on the breed of the cow and stage of milking. Milk from Jersey and Guernsey cows has been shown to have more of the larger-sized globules than does milk from Ayrshire and Holstein (8,29). Kernohan and Lepherd (26) studied the size distribution of milk fat globules during different milking times. They observed an increase in the average diameter of fat globule as milking progressed. Also, the number of globules per milliliter of milk increased from fore-milk to the residual strippings.

Milk fat is not a uniform substance. Extensive reviews of chemistry of milk fat are available in the literature (22,34). Triglycerides constitute the major portion of lipid material. Associated with the triglycerides, at the surface, are phospholipids. Phospholipids in conjunction with proteins form a layer around the lipid material (34,51). This adsorbed layer which helps the globule in maintaining its identity is termed "milk fat globule membrane" (MFGM). When milk or cream is subjected to mechanical agitation or stress, the MFGM ruptures. Churning has more distructive effect on the MFGM as compared to homogenization. Churning enables the lipid material of individual globules to coalesce and form a mass. Homogenization allows re-formation of the membrane, but with considerable modification (23,25).

The average milk fat globule diameter is reduced to one micron or less and the total surface area of lipid globules is increased from 4 to 10 times with homogenization (54). The increase in the total surface area is attributed to the association of new material with the MFGM to form a membrane-like structure over smaller but more numerous fat globules. Jackson and Brunner (23) showed the association of casein and non-casein serum proteins with the MFGM of homogenized milk. Keenan et al. (25) concluded that after homogenization a large proportion of the original MFGM remained associated with the fat globules. They indicated that the original membrane was spread over a large surface area. Greenbank and Pallansch (19) noted formation of new lipid-protein complexes when the surface of the fat phase was greatly extended by high-pressure homogenization. Results of studies (19,25) have shown that homogenization induced selective displacement of certain constituents of MFGM. Keenan et al. (25) reported displacement of about 20% of the phospholipid and cholesterol originally associated with globules into the serum phase.

Use of Homogenization in Cheese Making

The altered morphology of the fat globule membrane because of homogenization is considered beneficial during curing of Blue cheese (5,30). Results of studies (10,24,28) showed the susceptibility of milk fat from homogenized milk to enzymatic action and production of desirable flavor compounds in Blue cheese. To obtain the beneficial effects, milk used for the manufacture of Blue-type cheeses is separated and the cream homogenized at pressures of 70.4 to 140.8 kg/cm^2 (500 to 1000 psig, respectively) (28,57). The skim milk is added back to the homogenized cream and made into cheese. Some plants may also homogenize cheesemilk for Blue cheese without any prior separation (28).

Although use of homogenized milk is not common in other cheeses, studies (15,32,40) have been done to learn the effects of the process on the properties of cheese curd and the quality of the finished cheese. Marquardt (32) reported improved cheese texture and reduced fat losses in whey when homogenized milk was used for Neufchatel cheese making. His study of cottage cheese made from homogenized skim milk showed the granular texture of cottage cheese can not be made smooth due to the lack of fat in skimmed milk used. He recommended homogenization pressures greater than 140.8 kg/cm^2 to improve texture of soft cheese varieties and minimize the fat losses in whey.

The action of rennet on homogenized and unhomogenized milks is not similar (39,45). With homogenized milk, the gel strength is reduced and rate of coagulation is increased (33). The damage to casein particles due to homogenization, and the adsorption of casein particles to the newly-formed fat globules were proposed to be the causes of decrease in rennet curd tension (39). Maxcy et al. (33) suggested that fat disrupts the continuity of gel structure and increasing the number of fat globules therefore increases the number of weak points. Similar conclusions were drawn by Sanders et al. (45) who observed that the curd-softening effect of homogenization is due primarily to the increase in dispersion of fat, with the dispersed fat acting as a physical hindrance to the aggregation of the casein micelles. Electron microscopy (15) showed smaller, more dispersed fat globules in cheese. The normal curd-making properties can be restored to homogenized milk by concentrating it or by addition of nonfat dry milk (33).

Quarne et al. (42) studied homogenization of milk as a means of increasing fat retention in curd produced by direct acidification. They recorded increased fat and solids-not-fat retentions with use of homogenized milk in Pizza cheese making. They reported higher cheese yields related to homogenization of milk. Peters (38) reported similar results and observed lower fat losses in whey and increased cheese yields with homogenization of milk. Green et al. (18) reported improved composition of Cheddar cheese made from homogenized concentrated milk. The improvement was attributed to increased fat and moisture retention. Though some aspects of the texture of mature cheese were improved, the free fatty acid contents were reported to be higher. A US patent was obtained by Wilson and Johnson (56) in 1938, for the use of homogenization in Cheddar cheese making. They claimed the oiling off or leakage of fat in cheese will be prevented by homogenizing the cream and adding it back to the skimmed cheesemilk.

MATERIALS AND METHODS

Cheddar cheese was manufactured from heat-treated milk homogenized at four pressures. In a given week, four vats of cheese representing the four treatments were made from milk derived from the same raw milk lot. Two vats of cheese were made on a single day, with the two milk treatments selected at random. A typical Cheddar cheese making procedure described by Chr. Hansen's Laboratory, Inc. (20) was followed for eight weeks.

Milk Preparation

About 725 kg (1600 lb) of milk were received each week from South Dakota State University (SDSU) Dairy Research and Production Unit. At the SDSU Dairy Products Laboratory, the milk was clarified and heat-treated at 63°C for 30 minutes. Portions of 181.5 kg (400 lb) each were then passed through Gaulin two-stage homogenizer (Haskon Inc., Equipment Division, 2283 Univ. Ave., St. Paul, MN), at pressures of 0, 35.2, 70.4, and 140.8 kg/cm^2 (0, 500, 1000, and 2000 psig, respectively). Only the first-stage homogenizer valve was activated during the operation of the homogenizer. Cheddar cheese made from milk pressure-treated at 0 kg/cm^2 was considered as control in this project for comparison purposes. The other three homogenizer pressures were considered as experimental treatments. Immediately after homogenization, milk was chilled to 4.4°C (40°F) and collected in 38-liter cans. Two of the homogenized portions were selected at random and transferred into 210-liter stainless steel vats for Cheddar cheese making. The other two portions were stored overnight at 5°C and were used for cheese making the following day.

Cheese Manufacture

The two selected portions of milk were poured into 210-liter vats and warmed to 31°C (88°F). The milks were inoculated with 20 ml each of thawed Superstart frozen concentrate culture (Marshall Products Division, Miles Laboratories, Inc., P.O. Box 592, Madison, WI). During a week, one of two multiple strain starters, designated either M or L, was used. The cheesemilk was allowed to ripen for 30 min, the acid developement being monitored by titratable acidity (TA). After the required .005% increase in TA was attained, annatto coloring (6.6 ml/ 100 kg milk) and calcium chloride (.02% by weight of milk) were added to the vats and mixed well into the milk. At the same time, 36 ml of rennet extract (100% strength; 20 ml per 100 kg milk) which had been diluted to 20 times its volume with cold water was blended into the cheesemilk.

After adding the rennet extract, milk was allowed to set for 40 min, then the curd was cut using vertical and horizontal stainless steel knives with wires .93 cm apart. The coagulum was cut lengthwise of each vat with the horizontal knife. Cubes of uniform size were obtained by drawing the vertical knife through the curd once lengthwise and once breadthwise of the vat.

The curd cubes were allowed to heal for 15 min after cutting and then the curd and whey mixtures were stirred and cooked. During the initial 20 min of the cooking phase, temperature was raised at the rate of .55°C (1°F) for each 4 min period. The temperature was then raised to final cook temperature of 38°C (101°F) in 10 minutes. Occasional stirring of curd was followed throughout this period. The curd was stirred continuously for 30 more min, while the temperature was maintained at 38°C.

The titratable acidity of whey was determined at the end of the cook period and periodically thereafter. The whey was drained when the TA reached .12 to .13% acid as lactic. The curd was allowed to mat in the back of the vat, after which it was cut into 10-cm wide slabs. The slabs were piled and turned every 15 min, with the temperature of the vat being maintained at 32°C (89.6°F). The titratable acidity of whey drippings was monitored throughout the cheddaring process.

Curd slabs were milled into strips 6 cm (2.4 in) long and 1.6 cm (.63 in) wide when the TA reached .45% acid as lactic. The milled curd was aerated for 10 min by manual forking. Salt was added at the rate of 2% of estimated curd weight, in two applications, and blended for 15 min. Curd was then packed in stainless steel rectangular hoops holding about 10 kg (22 lb) and pressed overnight in a pneumatic press.

The cheese blocks were weighed the next day, cut into 8 rectangular portions weighing 1.25 kg (2.75 lbs) each and sprayed with aqueous solution of potassium sorbate (20% w/v). The blocks were placed in Cryovac plastic bags and vacuum packed employing a Tipper Clipper (Tipper Tie Division, Rheem Manufacturing Company, Union, NJ). The bags were immersed in a Cryovac Shrink Tank (Allcraft Manufacturing Company, Inc., Cambridge, MA) then waxed. Cheeses were then placed in a curing room for 3 months at 7-10°C (44-50°F) and 75% relative humidity.

Sampling

Raw milk samples were collected as soon as milk was received. Samples of heat-treated homogenized milks were taken from cheese vats. The milk was stirred well prior to sampling to obtain a representative sample.

Whey, after cooking, was drained and collected in 38-liter cans. A representative sample taken from these cans was designated as "sweet whey sample". A similar sample was obtained from the combined collection of whey drippings after salting and during pressing. This sample was designated as "salt whey sample".

Cheese samples for initial analyses (0 day) were taken from cheese pressed overnight. Subsequent samples were collected at 30-day intervals to follow compositional and sensory changes during the curing period of 90 days.

All samples were collected in 532 ml (18 oz) Whirl-Pak plastic bags (NASCO, 901 Janesville Avenue, Fort Atkinson, WI) and held at 4°C except while being subsampled for analyses or evaluation.

Sample Componential Analysis

Samples from homogenized milks were tested for bacteriological quality. These samples were analyzed for Standard Plate Count (SPC), Psychrotrophic Bacterial Count (PBC), and Coliform Count (CC) according to the Standard Methods procedures (2). Nitrogen distribution in all milk samples was determined by the method described by Rowland (44). The effect of homogenization pressures on size distribution of milk fat globules was studied by electronic counting employing a Coulter Counter Model ZB1, equipped with Coulter Model MHR MCV/Hct/RBC Computer (Coulter Electronics, Inc., Hialeah, FL).

Kjeldahl nitrogen procedure outlined by the Association of Official Analytical Chemists (AOAC) (3) was employed to determine the protein content of cheese and the sweet and salt whey samples. Total solids and fat of milk, cheese, and whey samples were determined by the Mojonnier method (37), as specified for each individual product. Fat content of whey samples was also analyzed by a modified n-butanol Babcock method (3) to compare agreement of results with those from the Mojonnier procedure. Whey samples of 9 g were used in 18-g Babcock bottles and centrifuged for 6 minutes after addition of water to ensure complete separation of milk fat. Fat and protein contents of cheese were determined on samples obtained on 0 day and 90 days; total solids contents were determined throughout the curing period. Total ash contents of milk, cheese, and whey samples were determined by the AOAC method using porcelain crucibles (3). Quantab chloride titration strips (Ames Co., Division Miles Laboratories, Inc., Elkhart, IN) were employed to estimate the salt content in cheese and whey samples (21). Cheese curd lost in whey as fines was estimated by the method described by Rabb et al. (43)

The ripening of cheeses was followed by determining water-soluble nitrogen (WSN) fractions (52). Breakdown of fat in cheese throughout the ripening period was followed by analyzing for free fatty acids (Acid Degree Value) (50). Cheese pH was measured using a Corning Model 7 pH meter (Corning Medical, Corning Glass Works, Medfield, MA) and Orion Needle combination pH electrode (Orion Research Inc., Cambridge, MA).

Organoleptic Evaluations

Cheeses were evaluated for flavor and body & texture by a panel of five trained members. The sensory evaluations started at one month of age of cheese and were conducted at 30-day intervals for a 3-month period. To eliminate any bias, samples were coded and offered to the panel in a random order. The flavor of cheese samples was scored on a scale of 1 to 10; the body & texture was scored on a scale of 1 to 5. The score card designed by the American Dairy Science Association-Dairy and Food Industries Supply Association (ADSA-DFISA) was used to grade all cheese samples.

Yields of Cheddar Cheese

Yields were calculated as kilograms cheese received per 100 kg of cheesemilk. For final comparisons, yields were adjusted to a base of 63% solids cheese.

Statistical Analysis

The data were evaluated statistically using analysis of variance procedure from Statistical Analysis System (SAS Institute Inc., Cary, NC). The means of variables of treatments were compared among each other and against those of the control, employing Waller-Duncan k-ratio test (49).

RESULTS AND DISCUSSION

Composition of Cheesemilk

The average composition of milk used for Cheddar cheese making is shown in Table 1. The low total solids content (11.59%) of milk during the months of July-August, at which time the cheese was made, is typical. A study done by Yee and Spurgeon (58) established that the total solids content of milk is low during summer months in South Dakota. The average true protein content of milk was derived from Kjeldahl nitrogen less non-protein nitrogen and was 2.69%.

The bacteriological quality of milk plays an important role in the yield as well as quality of Cheddar cheese. The cheesemilk used in this project was of good quality (Table 2). After the milk was heat-treated, the counts of psychrotrophic and coliform bacteria were both less than 1 per ml of sample plated. No colonies were detected in plates with higher dilutions of the sample. The Standard Plate Counts ranged from 2500 to 7800 for the lowest to the highest homogenization pressure. The milks homogenized at different pressures were derived from the same lot of raw milk; the significant increases ($P<.01$) in the SPC with increasing homogenization pressure likely were the result of breaking apart of clumps of bacteria.

Nitrogen distributions indicated that homogenization had no detectable effect on the distribution of nitrogen fractions in milk (Table 3). Casein and whey protein nitrogen constituted 76.11 and 18.14% respectively of total nitrogen of milk. The non-protein nitrogen constituted 6.64% of the total nitrogen.

Whey Composition

The sweet and salt wheys obtained from Cheddar cheese making were analyzed for proximate composition (Tables 4 and 5). Statistical comparisons of values for components other than total solids were made after calculating the ratio of the components to their respective total solids. Even though a decrease in total solids levels of wheys from homogenized milks was noticed, there was no definite relation between the homogenization pressures used and the total solids levels in the sweet and salt wheys. It was true that sweet whey from milk homogenized at the highest pressure (140.8 kg/cm^2) had the lowest total solids content of 6.68% as compared to 6.88% in the control cheese whey. The fat content of control sweet whey was .38%. With progressive increases in homogenization pressure, the fat loss in sweet whey decreased from .35 to .29% but was shown as statistically not significant ($P>.05$). Noticeable decreases ($P<.01$) were observed in salt whey where the fat loss was 1.49% for control as compared to .73% for the highest homogenization pressure (140.8 kg/cm^2). Similar observations were reported by previous workers (15,18,38). Although not reported in a tabular form, the percent fat values determined by the Mojonnier method and modified n-butanol Babcock method were similar.

The protein contents of experimental sweet and salt wheys were not different (P>.05) than those of controls (Tables 4 and 5). The ash and salt contents of sweet wheys were not affected by homogenization of milk. The loss of curd fines in sweet wheys were .05-.06 g of 63% solids curd per 40 ml of sample. The curd loss was similar in experimental and control sweet wheys. In contrast, higher losses of curd fines were observed in control as well as experimental salt wheys. Average loss in control salt whey was .23 g of 63% solids curd per 40 ml sample. A higher (P<.05) loss of .25 g of 63% solids curd per 40 ml sample was found only in salt whey derived from milk homogenized at 140.8 kg/cm². Salt wheys derived from milks homogenized at the other two pressures had losses of .24 g of 63% solids curd per 40 ml sample, which was not different (P>.05) than curd loss in control salt whey.

The total solids of salt wheys from experimental milks were lower than that of the control salt whey. No defined relation between the homogenization pressures and the total solids contents was noticed. The salt and ash contents of salt whey revealed a decreasing trend with increasing homogenization pressure but no linear relationship was noted.

Cheddar Cheese Composition

The average composition and yields of Cheddar cheeses are shown in Table 6. Components other than total solids were corrected to a base of 63%-solids cheese to facilitate comparison. Total solids content of cheeses made from homogenized milks were not different ($P>.05$) than the total solids content of the control cheeses, with the exception of the cheese made from milk homogenized at 140.8 kg/cm^2 ($P<.01$). These findings correlate with the reports by earlier workers (40) of no definite relation between the moisture content of cheese and homogenization pressures used. Normally, during the ripening period, some moisture is lost, increasing the total solids content. However, no variation ($P>.05$) in the total solids content of the cheeses in this study was found during the aging period. This could have been because of the short period of curing during which time there was not much moisture loss.

The increases in the total solids content of cheeses by the use of homogenized milks may be explained as a result of increased retention of milk fat in cheese curd. Fat content of cheeses had a linear relation ($r= .978$) with the homogenization pressures used. Earlier research (15,18,30,38,40) with the use of homogenized milk in cheese making showed increases in fat content in cheeses with respect to homogenization pressures. The fat content of control cheese was 32.09% which accounted for 50.94% of total solids. With progressive increases in homogenization pressures, the fat content increased to 32.19% and finally to 32.55%. Fat as percent of total solids increased from 51.10 to 51.67%. The increase in fat as percent of total solids of cheeses can be attributed to the improved fat retention property of cheese curd with homogenization of cheese milk. This property was observed during the pressing of cheese curd and noted in the decreased fat losses in salt whey as compared to the control wheys (Table 5).

The effect of homogenization of milk on protein, ash, and salt contents of the cheese varied (Table 6). The average percent protein values of cheeses made from milk homogenized at 35.2 and 140.8 kg/cm^2 were slightly lower than that of control cheese, whereas a higher value was noted for the cheese made from milk homogenized at 70.4 kg/cm^2. These values were not statistically different ($P>.05$).

Lower ash contents ($P<.05$) were obtained in the cheeses made from milks homogenized at 70.4 and 140.8 kg/cm^2. Salt contents of 1.75% were desired during cheese making. The salt percent by weight of the cheese ranged from 1.66% for the control to 1.82% for cheese made from milk homogenized at 70.4 kg/cm^2.

Yields of Cheddar Cheese

As was reported by earlier workers (15,18,38,40), the yields of Cheddar cheese improved with the use of homogenized milk. The normal yields of Cheddar cheese with 37% moisture have been reported (28,57) to range from 9-10% by weight of cheese milk. The cheese yields obtained in this study were comparatively low; the average yield for composition-adjusted control cheese being 8.99% (Table 6). With progressive increases in homogenization pressure, the yields of cheeses increased to 9.17% ($P<.05$) for the lowest homogenization pressure (35.2 kg/cm^2) and to 9.26% ($P<.01$) for the highest homogenization pressure (140.8 kg/cm^2). These increases in the yield of cheese could be attributed to improved fat retention property of the cheese curd and lowered fat losses in the whey as induced by homogenization of cheese milk.

Ripening of Cheddar Cheese

The most important chemical change during ripening of cheese is the breakdown of protein. The protein breakdown results in release of water-soluble components such as peptides and amino acids (53). Normal aging of Cheddar cheese is indicated by increase in the percent soluble nitrogen and a corresponding decrease in the true protein value.

The protein degradation during aging was reflected in the lower protein values after 90 days of curing (Table 6). The percent decrease of protein after curing was calculated for each homogenization pressure and then compared statistically. The decreases in protein values for cheeses from homogenized milks were found not to be different ($P>.05$) than the decrease in protein values for the control cheese.

The soluble nitrogen (SN) values of cheeses made from homogenized milk were not different ($P>.05$) than those of the control cheeses (Table 7). This is an indication that homogenization of the cheese milk had no detectable effect on the protein degradation during the curing of the cheeses. The average soluble nitrogen values, however, increased ($P<.01$) with aging of the cheeses.

Enzymatic activity during the aging of cheese causes some of the lipid material to be hydrolyzed to free fatty acids causing a slight decrease in the percent fat of aged cheese (29,46). This occurrence was noted in both control and experimental cheeses (Table 6). The decrease of percent fat from 0 to 90 days was significant ($P<.05$) for all cheeses.

Acid degree value (ADV) of cheese is an indication of the amount of free fatty acids present in the product (12). Lipolysis and liberation of free fatty acids were of major concern in this study as the mechanical damage done to the fat globule membrane by homogenization is well known (23,25). As shown in Table 8, the fresh (0 day) cheeses had ADVs ranging from .96 for the control cheese to .98 for cheeses made from milk homogenized at 70.4 and 140.8 kg/cm^2. These values were not different than each other ($P<.05$). With progression in time, the ADVs of all cheeses increased. The highest ADV of 1.46, at the end of the curing period, was noted for cheese made from milk homogenized at 140.8 kg/cm^2. According to Deeth and Fitz-Gerald (12), ADVs of normal Cheddar cheese range from 1.2 to 1.8. Hence it can be stated that although an increase in ADVs of cheeses with the use of homogenized milks was noted, the increase was not detrimental to the quality of the product.

The average pH values for all cheeses during ripening are shown in Table 9. The fresh cheeses (0 day) had the lowest pH values. Wilster (57) indicated that three to four day-old Cheddar cheese had the lowest pH; as curing progressed, the active acidity decreased. The pH of all cheeses in this study increased during aging ($P<.05$). The increases in pH were similar ($P<.05$) for experimental cheeses and control cheese.

Organoleptic Quality of Cheddar Cheeses

The results of organoleptic evaluations of the experimental and control cheeses are listed in Tables 10 and 11. The experimental cheeses were scored lower ($P<.05$) than the control cheeses for flavor (Table 10). No appreciable increases in flavor scores were noted during the aging of all cheeses ($P>.05$). This probably could have been because of the short period the cheese was allowed to age. It has been noted by Foster et al. (17) that the developement of typical Cheddar cheese flavor occurs more slowly than do the changes in body. The most common criticism for all cheeses was 'lack of flavor'. During the final stages of aging, however, the cheeses were marked as having 'slight acid' flavor, which is normal for Cheddar cheese.

The scores for body & texture of experimental cheeses were lower ($P<.05$) compared to the scores of the control cheese (Table 11). The most common criticism was 'curdy' body. The scores of all cheeses improved with age, but the cheese made from milk homogenized at 140.8 kg/cm^2 had the lowest score of 2.98 on a scale of 1 to 5 after 90 days of aging.

CONCLUSIONS

The yields of Cheddar cheeses manufactured from homogenized milks increased with increases in homogenization pressure. The yields of cheeses from the lowest homogenization pressure (35.2 kg/cm^2) were 2% higher than that from unhomogenized milks. A yield increase of 3% over the control cheese yields was obtained with milk homogenized at 140.8 kg/cm^2. The increases in the yields of cheeses can be related to the decreases in fat loss in whey after salting and during pressing. All cheeses met the legal requirement of having at least 50% of dry matter as fat.

No detectable effect of homogenization of cheesemilk on protein hydrolysis during curing was found. Although the amounts of free fatty acids in cheeses increased with the use of homogenized milk, and with aging, the acid degree values of all cheeses were in acceptable range after 90 days curing. Organoleptic evaluations revealed that the body and texture of all cheeses improved during aging, but the scores decreased as the homogenization pressure increased. Scores for flavor of cheeses did not increase during aging. Lowest scores were given to the cheeses made from milk homogenized at the highest pressure.

Statistical analysis did not show differences ($P>.05$) in many aspects of quality for cheeses made from milk homogenized at 35.2 and 70.4 kg/cm^2. Homogenization of cheesemilk at these two pressures affected the matting property of curd, but still allowed satisfactory handling during cheddaring and hooping. Higher pressure (140.8 kg/cm^2) seemed to make the curd brittle and hard to handle, leading to greater losses of fines. Lower homogenization pressures (35.2 and 70.4 kg/cm^2) which give mild shearing to milk fat globules, increasing fat retention in Cheddar cheese, would be economically advantageous.

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TABLE 1: Average composition of milks used in the manufacture of Cheddar cheeses[1].

Component	Percent
Total solids	11.59
Fat	2.94
Protein[2]	2.69
Mineral ash	.69

[1]Values are means of eight replications.

[2](total nitrogen - non protein nitrogen) multiplied by 6.38.

TABLE 2. Microbial quality of heat-treated cheesemilks[1].

Bacterial tests	Homogenizer pressure on cheesemilk (kg/cm²)			
	0	35.2	70.4	140.8
	(Count/ml)			
Psychrotrophs	<1	<1	<1	<1
Coliforms	<1	<1	<1	<1
Standard Plate Count	2500	2600**	4500**	7800**

**Different than control (P<.01).

[1]Values are means of eight replications.

TABLE 3. Nitrogen distribution in cheesemilks[1].

Nitrogen fraction	Homogenizer pressure on cheesemilk (kg/cm²)				
	Raw	0	35.2	70.4	140.8
	(%)				
Total	.46	.44	.45	.46	.45
Protein	.43	.41	.42	.43	.42
Casein	.34	.33	.35	.35	.35
Whey protein	.09	.08	.08	.08	.08
Non-protein	.03	.03	.03	.03	.03

All differences nonsignificant (P>.05).

[1]Values are means of eight replications.

TABLE 4. Average composition of "sweet wheys" obtained from Cheddar cheese making[1].

Component	Homogenizer pressure on cheesemilk (kg/cm²)			
	0	35.2	70.4	140.8
	(%)			
Total solids	6.88[a]	6.80[ab]	6.83[ab]	6.68[b]
Fat	.38[a]	.35[a]	.30[a]	.29[a]
Protein	.83[a]	.79[a]	.81[a]	.80[a]
Salt	.16	.16	.16	.16
Ash	.55	.55	.56	.55
Curd[2]	.06	.05	.06	.06

[a,b] Values in same row with same superscript are not different (P>.05).

[1]Values are means of eight replications.

[2]Grams of 63% solids curd/40 ml of sample.

TABLE 5. Average composition of "salt wheys" obtained from Cheddar cheese making[1].

Component	Homogenizer pressure on cheesemilk (kg/cm^2)			
	0	35.2	70.4	140.8
	(%)			
Total solids	17.43[a]	15.99[b]	16.31[b]	15.07[d]
Fat	1.49[a]	1.05[d]	.93[d]	.73[e]
Protein	1.04[a]	1.12[a]	1.07[a]	1.05[a]
Salt	7.96[a]	6.60[b]	7.21[ab]	6.69[ab]
Ash	9.86[a]	8.76[bc]	9.41[ab]	8.29[c]
Curd[2]	.23[a]	.24[a]	.24[a]	.25[b]

a,b,c Values in same row with same superscript are not different ($P>.05$).

d,e Values in same row with same superscript are not different ($P>.01$).

[1]Values are means of eight replications.

[2]Grams of 63% solids curd/40 ml of sample.

TABLE 6. Average composition and yields of Cheddar cheese made from homogenized milks[1,2].

Component	Homogenizer pressure on cheesemilk (kg/cm²)			
	0	35.2	70.4	140.8
	(%)			
Total solids				
0 days	63.99[a]	63.34[a]	63.39[a]	65.29[c]
90 days	63.64[ab]	63.42[a]	64.62[bc]	65.25[c]
Fat				
0 days	32.09[a]	32.19[ab]	32.46[b]	32.55[b]
As dry matter	50.94	51.10	51.52	51.67
90 days	31.30[a]	31.25[ab]	31.76[b]	31.58[b]
Protein				
0 days	24.51[a]	24.36[a]	24.56[a]	23.95[a]
As dry matter	38.90	38.67	38.98	38.02
90 days	16.56[a]	16.32[a]	16.38[a]	16.04[a]
Ash	3.71[a]	3.71[a]	3.66[b]	3.62[b]
Salt (NaCl)	1.66[a]	1.74[b]	1.82[c]	1.69[a]
Yield[3]	8.99[a]	9.17[b]	9.25[b]	9.26[d]

[a,b,c]Values in same row with same superscript are not different (P>.05).

[d]Values in same row with same superscript are not different (P>.01).

[1]Values are means of eight replications

[2]Components other than total solids are adjusted to 63% solids cheese.

[3]Composition-adjusted kilograms of cheese/100 kg of milk.

TABLE 7. Average soluble nitrogen values of Cheddar cheeses during ripening[1].

Age of cheese (Days)	Homogenizer pressure on cheesemilk (kg/cm²)			
	0	35.2	70.4	140.8
	(% soluble nitrogen)			
0	.26	.28	.24	.26
30	.93	.95	.91	.94
60	1.14	.98	.98	1.14
90	1.19	1.15	1.10	1.11

All differences are nonsignificant (P>.05).

[1]Values are means of eight replications.

TABLE 8. Acid degree values (ADV) of Cheddar cheeses made from homogenized milks[1].

Age of cheese (Days)	Homogenizer pressure on cheesemilk (kg/cm^2) 0	35.2	70.4	140.8
	(ADV)			
0	.96[a]	.97[a]	.98[a]	.98[a]
30	1.05[a]	1.10[b]	1.18[c]	1.21[c]
60	1.14[a]	1.22[b]	1.27[c]	1.31[c]
90	1.32[a]	1.33[a]	1.39[b]	1.46[c]

[a,b,c] Values in same row with same superscript are not different (P>.05).

[1]Values are means of eight replications.

TABLE 9. pH of Cheddar cheeses during aging[1].

Age of cheese (Days)	Homogenizer pressure on cheesemilk (kg/cm²) 0	35.2	70.4	140.8
	(pH)			
0	4.98	5.01	5.03	4.99
30	5.06	5.04	5.06	5.04
60	5.09	5.06	5.09	5.09
90	5.14	5.12	5.14	5.16

All differences are nonsignificant (P>.05).

[1]Values are means of eight replications.

TABLE 10. Flavor values of Cheddar cheeses[1].

Age of cheese (Days)	Homogenizer pressure on cheesemilk (kg/cm²) 0	35.2	70.4	140.8
	(Score[2])			
30	8.18^{a}	7.90^{a}	7.88^{a}	7.83^{a}
60	8.33^{a}	7.98^{b}	8.00^{b}	7.50^{c}
90	8.43^{a}	8.13^{ab}	7.93^{b}	7.73^{b}

[a,b,c] Values in same row with same superscript are not different (P>.05).

[1]Values are means of eight replications.

[2]On basis of 1 to 10; 10 being no flavor defects.

TABLE 11. Body & texture values of Cheddar cheeses[1].

Age of cheese (Days)	Homogenizer pressure on cheesemilk (kg/cm²) 0	35.2	70.4	140.8
	(Score[2])			
30	3.20[a]	2.88[bc]	2.98[ab]	2.68[c]
60	3.65[a]	3.25[b]	3.28[b]	2.80[c]
90	3.88[a]	3.60[a]	3.23[b]	2.98[b]

[a,b,c]Values in same row with same superscript are not different (P>.05).

[1]Values are means of eight replications.

[2]On basis of 1 to 5; 5 being no body or texture defects.

APPENDIX

APPENDIX TABLE 1. Composition-adjusted Cheddar cheese yields for eight replications.

Homogenizer pressure on milk (kg/cm^2)			
0	35.2	70.4	140.8
(kg/100 kg milk)			
9.01	9.22	9.28	9.37
8.92	9.27	9.50	9.16
9.09	9.22	9.42	9.33
9.19	9.10	9.25	9.30
9.03	9.03	9.28	9.20
8.97	9.10	9.25	9.29
9.01	9.37	9.03	9.18
8.71	9.08	8.99	9.21

APPENDIX TABLE 2. Milk fat globule distribution in cheesemilks.

	Homogenizer pressures on cheesemilk (kg/cm^2)			
Setting[1]	0	35.2	70.4	140.8
	(No. of fat globules[2])			
5 - 10	6.22	6.04	6.10	5.87
10 - 15	7.53	7.94	8.39	8.60
15 - 20	5.99	5.36	5.60	4.10
20 - 25	4.31	3.89	2.10	1.69
25 - 30	2.98	2.10	1.21	.91
30 - 35	1.21	.99	.54	.39
35 - 40	.88	.53	.11	.10

[1]Coulter counter threshold values given as 'lower - upper'.

[2] Value x 10^7 globules/ml.